

1 WHAT IS CLAIMED IS:

2 1. A cryogenic gas delivery apparatus, comprising:

3 a chamber adapted to contain a cryogenic liquid and corresponding gas,
4 the liquid at a temperature below that of the ambient, the gas at a pressure above that of
5 the ambient;

6 at least one heat-conductive probe with a first portion exposed to the
7 ambient, so that the probe introduces thermal energy from the ambient into the chamber;
8 and

9 a passage in communication with the gas in the chamber to receive the gas
10 from the chamber for delivery to the user;

11 wherein the probe is mounted to move relative to the chamber in response
12 to variations in the pressure of the gas, thereby varying the amount of the thermal energy
13 introduced into the chamber.

1 2. The apparatus of claim 1, further comprising:

2 a delivery system configured to deliver the gas over time to the user, the
3 delivery system in communication with the passage to receive the gas from the chamber.

1 3. The apparatus of claim 2, wherein the delivery system comprises a pneumatic
2 conserver, the conserver having a sensing system adapted to discharge the gas in response
3 to inhalation by the user.

1 4. The apparatus of 3, wherein the conserver further comprises a reservoir charged
2 by the gas exiting the chamber, and wherein the sensing system is operatively connected
3 to the reservoir.

1 5. The apparatus of claim 1, further comprising a flow-rate controller in
2 communication with the passage, flow-rate controller having multiple settings for
3 delivering correspondingly different volumes of the gas over time.

1 6. The apparatus of claim 1, further comprising a fill system configured to fill the
2 chamber only partially with the liquid.

1 7. The apparatus of claim 6, wherein the fill system includes a fill tube terminating
2 in an opening approximately in the middle of the chamber, and a fill chuck connected to
3 the opposite end of the fill tube and having a fill chuck valve adapted to connect to a
4 source of the cryogenic liquid;

5 wherein the apparatus further comprises a manifold secured to one end of
6 the chamber, the manifold having been defined so that the fill chuck and the fill tube at
7 least partially extend therethrough, the fill chuck secured relative to the manifold to
8 define an insulated space between the fill chuck and the manifold over substantially all of
9 the length of the fill chuck, whereby the liquid passing through the fill chuck absorbs
10 minimal heat from the manifold.

1 8. The apparatus of claim 6, wherein the fill system has a trapping mechanism to
2 reduce leakage of the liquid out of the chamber which would otherwise occur during
3 filling of the chamber from approximately 40% to 50% of capacity of the chamber.

1 9. The apparatus of claim 6, wherein the fill system includes a fill chuck with a first
2 sealed opening adapted to unseal in response to connecting the fill chuck to a base unit
3 for filling, and a second sealed opening adapted to unseal in response to excess pressure
4 of the gaseous oxygen in the chamber.

1 10. The apparatus of claim 1, further comprising a double-wall container, the inner
2 wall of which defines the chamber and the outer wall extends in spaced relation to the
3 inner wall to define an insulating region between the inner wall and the outer wall, the
4 insulating region being substantially evacuated of air to form a vacuum.

1 11. The apparatus of claim 1, wherein the probe comprises a first probe with the first
2 portion located in the chamber and the second portion located outside the chamber, the
3 apparatus further comprising a second probe secured within the chamber and having a

4 second probe surface opposing the first portion of the first probe to transfer heat from the
5 first probe to the second probe.

1 12. The apparatus of claim 11, further comprising a sleeve secured to extend into the
2 chamber and sized to slidably receive the first probe therein in opposing relation to the
3 second probe.

1 13. A portable liquid oxygen system for delivering gaseous oxygen to a user, the
2 system comprising:

3 a container sufficiently insulated from the thermal energy of the ambient
4 to hold oxygen in both the liquid phase and the gas phase inside the container; and

5 a delivery system having an inlet for receiving the oxygen in the gas phase
6 from the container, an outlet for connecting to the user to deliver the gaseous oxygen, and
7 a conserver connected between the inlet and the outlet and operable in response to
8 inhalation to deliver the gas to the use.

1 14. The system of claim 13, further comprising a thermo-pneumatic regulator secured
2 to the container to vary the amount of thermal energy transferred to the container in
3 response to variations in the pressure of the gaseous oxygen in the container.

1 15. The system of claim 14, wherein the container includes an inner wall defining a
2 volume, the inlet of the delivery system located relative to the volume of the container to
3 reduce unintended loss of the liquid phase from the container irrespective of how the user
4 may orient the liquid oxygen system during use thereof.

1 16. The system of claim 13, further comprising a fill system configured to fill the
2 container only partially with oxygen in the liquid phase, thereby defining a liquid oxygen
3 volume and a headspace of pressurized oxygen gas in the container.

1 17. The system of claim 16 wherein the inlet includes a sleeve extending into the
2 container and ending at an opening in the container, the opening spaced from the inner
3 wall of the container and positioned approximately in the middle of the container,

4 whereby the opening of the inlet cannot be located in the volume of oxygen in the liquid
5 phase, irrespective of the orientation of the container.

1 18. The system of claim 14, wherein the regulator comprises a heat-conductive,
2 elongated member having a first portion located in the container and exposed to the
3 temperature therein and a second portion connected to the first portion and exposed to the
4 ambient temperature.

1 19. The system of claim 18, wherein the elongated member includes an inner surface
2 exposed to the pressure of the container and mounted to move in a first direction when
3 the pressure exceeds an upper threshold, the regulator adapted to transfer less thermal
4 energy to the container in response to the movement of the elongated member in the first
5 direction.

1 20. The system of claim 19, wherein the regulator further includes a biasing
2 mechanism to move the inner surface in a second direction when the pressure falls below
3 a lower threshold, the regulator adapted to transfer more thermal energy to the container
4 in response to movement of the elongated member in the second direction.

1 21. A portable, liquid oxygen system for delivering oxygen gas to a user, the system
2 comprising:
3 a container sufficiently insulated from the ambient to hold oxygen in the
4 form of both liquid oxygen and oxygen gas, the container characterized by a range of
5 evaporation rates at which the liquid oxygen is evaporated within the container to become
6 the oxygen gas;
7 a fill system configured to fill the container only partially with the liquid
8 oxygen to define a volume of liquid oxygen therein and a volume of pressurized oxygen
9 gas therein;
10 a delivery system having an inlet connected to the volume of oxygen gas
11 for receiving the oxygen gas from the container, and an outlet for connecting to the user
12 to deliver the oxygen gas;

13 a thermo-pneumatic regulator adapted to detect variations in the pressure
14 of the volume of the oxygen gas, and to increase the evaporation rate in response to the
15 detection of a predetermined drop in pressure of the volume of the oxygen gas, and to
16 decrease the evaporation rate in response to the detection of a predetermined increase in
17 pressure of the volume of the oxygen gas, whereby the regulator regulates the pressure of
18 the volume of the oxygen gas to remain within a selected baseline pressure range;
19 wherein the regulator is adapted to charge the delivery system with the
20 oxygen gas in sufficient amounts to fulfill the user's breathing needs as the liquid oxygen
21 is evaporated within the container.

1 22. The apparatus of claim 21,
2 wherein the apparatus is substantially cylindrical and has opposite ends,
3 the apparatus having a base defined at one of the ends and a head defined at the other of
4 the ends;
5 wherein the container has a top, a bottom, and a longitudinal axis
6 extending between the top and the bottom, the head being secured to the top of the
7 container, the container having a neck located in the top, the neck defining a passage
8 between the head and the container, the inlet of the delivery system including a sleeve
9 extending longitudinally from the neck into the container and positioned approximately
10 in the middle of the container;
11 wherein the fill system comprises a fill chuck and a fill tube, the fill chuck
12 secured to the head and extending outwardly from the longitudinal axis, the fill tube
13 having one end secured to the fill chuck extending longitudinally into the container
14 through the sleeve;
15 wherein the fill system further includes a vent-to-fill valve operatively
16 connected to the fill chuck, the delivery system further including a flow-rate controller
17 and a conserver located between the inlet and the outlet for delivering a selected amount
18 of the gas over time, the outlet terminating in a nozzle adapted to connect to a gas line for
19 the user to breathe through;
20 wherein the head includes a circumferential sidewall;

21 wherein the flow-rate controller, the vent-to-fill valve, the fill chuck, and
22 the nozzle are secured to the head at respective angular locations and are located to be
23 accessible by the user from the circumferential sidewall.

1 23. The apparatus of claim 22, wherein the regulator includes at least one probe
2 extending at least partially into the container, the probe being slidably received in the
3 neck of the container.

1 24. The apparatus of claim 22, wherein the head includes a manifold positioned
2 adjacent to the container along the longitudinally axis, and further comprising a conserver
3 positioned longitudinally adjacent to the manifold.

1 25. The apparatus of claim 24, wherein the manifold has an inner manifold wall
2 defining a manifold chamber, the manifold chamber in communication with the volume
3 of pressurized oxygen gas and with the regulator.

1 26. A regulator for a cryogenic gas delivery apparatus, the apparatus containing the
2 liquid at a temperature below a higher, ambient temperature, and the gaseous phase being
3 above ambient pressure, the regulator comprising:

4 at least one probe having first and second portions, the first portion being
5 positioned relative to the volume of the gas to expose the first portion to the pressure and
6 temperature of the volume of gas, the second portion being located to be exposed to the
7 higher, ambient temperature to conduct heat from the ambient to the volume;

8 wherein the first portion is configured to increase the conduct of heat to
9 the volume of liquid in response to the first portion being exposed to a decreasing
10 pressure of the volume of gas and to decrease the conduct of heat to the volume of gas in
11 response to the first portion being exposed to an increase in the pressure of the volume of
12 gas.

1 27. The regulator of claim 26, wherein the probe comprises an elongated member
2 having a head portion and an end portion, the head portion having inner and outer
3 surfaces, the inner surface exposed to the pressure of the volume of the gas, the pressure

4 on the inner surface biasing the elongated member away from the volume of gas, the
5 outer surface exposed to the temperature of the ambient, the end portion having a surface
6 extending into the volume of the gas; and a biasing mechanism to bias the elongated
7 member toward the volume of the gas, whereby the amount of heat transferred to the
8 volume of gas varies depending on the location of the elongated member relative to the
9 volume of the gas.

1 28. The regulator of claim 26, further comprising a passage through which gas in the
2 gaseous phase may flow from the volume of the gas and past the first portion of the probe
3 for delivery of the gas in the gaseous phase.

1 29. The regulator of claim 26, further comprising a seal disposed between the first
2 and second portions of the probe, the seal having a first side exposed to ambient pressure
3 and a second side exposed to the pressure of the volume of the gas, the seal engaging the
4 probe sufficiently to maintain the ambient pressure and the higher pressure of the volume
5 on respective sides of the seal.

1 30. A method of charging a liquid oxygen system, comprising the steps of:
2 providing an insulated container with a vent for discharging excess oxygen
3 and a passage in communication with the vent, the passage having an opening at a
4 location spaced from the inner wall of the container;
5 initiating the filling of the container with oxygen from a supply of liquid
6 oxygen under pressure by connecting the container to the supply;
7 continuing the filling process to fill the volume available in the container
8 only partially with liquid oxygen, the filling process continuing until the volume of the
9 liquid oxygen in the container reaches a level high enough so that the liquid oxygen
10 enters the opening of the passage and exits the vent in a fashion discernable to the user
11 charging the system; and
12 disconnecting the container from the supply once the liquid oxygen is
13 discerned to be exiting from the vent, whereby the container is charged with the partial
14 amount of the liquid oxygen resulting from the filling process.

1 31. The method of claim 30, wherein the opening is substantially in the middle of the
2 volume defined by the insulated container, and further comprising the step of continuing
3 the filling process until the volume of the container is about 50% filled with the liquid
4 oxygen.

1 32. The method of claim 30, further comprising the step of introducing thermal
2 energy from the ambient into the container by means of a thermally conductive path, the
3 path exposed on one end to the temperature of the ambient and on another end to the
4 volume defined by the insulated container, the introduction of thermal energy being
5 sufficient to increase the pressure within the insulated container to an operational,
6 baseline pressure.

1 33. The method of claim 32, wherein the insulated container has a given evaporation
2 rate when the system is charged, and further comprising the step of introducing thermal
3 energy into the insulated container before the system is charged to create an evaporation
4 rate higher than the given evaporation rate, and thereby shorten the time to charge the
5 system.

1 34. A method of dispensing oxygen gas from a liquid oxygen system, comprising the
2 steps of:
3 providing an insulated container with a chamber adapted to be only partly
4 filled with oxygen in the liquid phase, thereby creating a liquid oxygen volume and a
5 volume of oxygen gas in the chamber;
6 maintaining the volume of the oxygen gas at pressures above ambient;
7 dispensing the oxygen gas to a recipient through a passage in
8 communication with the volume of the oxygen gas;
9 wherein the step of dispensing the oxygen including receiving the oxygen
10 gas through the passage irrespective of the orientation of the chamber.

1 35. The method of claim 34, wherein the dispensing step including not receiving in
2 the passage any dispensable amounts of the oxygen in the liquid phase, no matter how the
3 container may be turned during use.

1 36. The method of claim 34, wherein the dispensing step further includes depleting
2 the liquid oxygen in the container at rates substantially independent of the orientation of
3 the container.

1 37. The method at claim 34, further comprising the step of introducing thermal
2 energy into the insulated container through a heat conductive path between the ambient
3 and the chamber.

1 38. The method of claim 37, wherein the step of introducing thermal energy further
2 includes increasing the evaporation rate in response to a decrease in the pressure of the
3 volume of gas and decreasing the evaporation rate in response to an increase in the
4 pressure of the volume of gas.

1 39. The method of claim 38, further comprising the steps of exposing more of the
2 heat-conductive path to the inside of the chamber to increase the evaporation rate and
3 exposing less of the heat-conductive path to the inside of the chamber to decrease the
4 evaporation rate.